SYNOPSIS OF P. G. RESEARCH PROJECT

1.	**Name of the Student**	**:**	KATARIYA YOGESHBHAI PRAVINBHAI
2.	**Registration No.**	**:**	1010125009
3.	**Faculty**	**:**	Agriculture
4.	**Name of the Degree Submitted for**	**:**	Ph.D. (Agri.)
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7.	**Name of Major Guide**	**:**	Dr. M. G. Valu Research Scientist (cotton) Cotton Research Station Junagadh Agricultural University, Junagadh
8.	**Title of Research Project**	**:**	**IDENTIFICATION OF SUPERIOR PARENTS AND HYBRIDS BASED ON HETEROSIS, COMBINING ABILITY, GENE ACTION AND STABILITY IN COTTON (*Gossypium hirsutum* L.)**

9. Introduction

Cotton, also known as the "king of fiber," is an important cash crop that has a significant impact on global social and economic affairs. Cotton's fiber quality is superior to that of any other fiber crop. And it is also known as “White Gold”.

In both the old and new worlds, *Gossypium* species were domesticated. It provides goods like lint, oil, hulls, linters and seed meal. Four out of fifty species in the genus *Gossypium*, which belongs to the *Malvaceae* family, are typically cultivated. *Gossypium hirsutum* L. and *Gossypium barbadense* L. two of the four cultivated species are tetraploids (2n=4x=52) and referred as "new world cottons." On the other hand, the old world cottons, *Gossypium arboreum* L. and *Gossypium herbaceum* L. are diploids (2n=2x=26). India is the only country, where all cultivated species of cotton *viz., Gossypium arboreum* L*., Gossypium herbaceum* L*., Gossypium hirsutum* L. and *Gossypium barbadense* L. are grown.

India is the second largest producer of cotton in the world, after China, with 299.26 lakh bales (each of 170 kg) grown on about 113.60 lakh hectares of land. India's

average productivity is 448 kg/ha. With 23.92 lakh hectares of land, Gujarat is the second largest growing state in India and produces 84.01 lakh bales which is highest among the states. The state's average cotton productivity (597 kg/ha) is greater than the national average (Anon., 2025).

Cotton predominantly self-pollinated, often cross-pollinated and suitable for heterosis breeding, according to Simpson (1954). The Bt gene's introduction into cotton has made hybrid cotton more important since it has a high potential yield, good fiber qualities, greater adaptability and a high level of resistance to biotic and abiotic challenges. Furthermore, compared to the land races, hybrid cultivars are appear better and extremely uniform. Additionally, hybrid production contributes to the growth of the nations seed industries, creates employment opportunities and increases foreign exchange through exporting excess produce. India's cotton production has become self-sufficient thanks in large part to hybrids. The introduction of the world's first cotton hybrid, Hybrid-4 by the late Dr. C. T. Patel in 1971 at the Main Cotton Research Station in Surat, G.A.U., gave enhancement to cotton industry of India. Several high-yielding hybrids were thereafter introduced in the early and late 1970s. In addition to providing fiber for the textile industry, the cotton crop's seed which is high in oil (18–24%) and protein (20–40%), also contributes to the feed and oil industries. Cotton production involves an estimated 350 million workers, either on farms or in transportation, ginning, baling and storage.

For a plant breeder to choose parents who might produce good segregants in a hybridization program, understanding the genetic value of germplasm is an essential first step. The most significant genetic approach for increasing yield potential is the commercial exploitation of heterosis, which has led to the creation of several high-yielding hybrids. A thorough genetic assessment of the parents' combining ability (the ability of a genotype to pass on its superiority to its crosses) would be necessary for the creation of better high-yielding varieties or the best hybrids for commercial cultivation. Combining ability analysis helps in the identification of appropriate parents for hybridization and superior cross combinations, as well as in the assessment of inbred or genotype in terms of genetic value. Additionally, it measures gene action involved in the inheritance of different characteristics.

The line × tester analysis technique has been widely utilized to examine the degree of heterosis for yield and yield contributing characters as well as to evaluate the combining ability of parents and crosses for various quantitative characters. The

development of the methods of breeding to be used for crop improvement greatly benefits from an understanding of nature and the extent of gene action influencing yield and yield components.

10. Practical Utility of the Research Project

The present research offers useful information for encouraging cotton improvement initiatives. Finding hybrids with stable and superior performance is aided by evaluating the types and magnitude of heterosis for yield and its component attributes in different environments. These heterotic combinations are directly helpful to generate commercial hybrids that can sustain high productivity in the face of shifting climate conditions.

A high yielding genotype may or may not transmit its superiority to the progenies, so the outcome of a breeding program depends largely on useful gene combinations in the form of high combining inbreds. For the development of superior hybrids, information on combining ability is a prerequisite that is used to identify the desirable parents and cross combination and also provides information on the type of gene action involved in the inheritance of various characters. Plant breeders are very concerned about the choice of suitable parents for evolving better varieties. When selecting suitable parental material for a plant breeding program, the combining ability study is a useful tool for differentiating between good and poor combiners. The creation of the breeding techniques to be used for crop improvement greatly benefits from an understanding of nature and the extent of gene action influencing yield and its components.

Crop yield is a quantitative characteristic that typically shows significant interactions between genotype and environment. As a result, there are significant environmental variations in the genotypes' yield performance. The G × E interaction makes it more difficult to choose genotypes that perform better because test genotype performance rankings can vary depending on the environment (Cooper and DeLacy, 1994). G × E interactions are typically seen as a barrier to crop advancement in the target region (Kang, 1998), but they can also be seen as a reflection of genotype adaption differences that can be taken benefit of by testing strategy modifications or selection. Changes in the environment have a significant impact on the phenotypic expression of quantitative features. Depending on their type and strength, G × E interactions may influence estimates of gene effects and combining ability for different traits that are sensitive to environmental changes. These characteristics are less susceptible to

selection. Therefore, to provide greater prediction and gain under selection, it is essential to evaluate the sensitivity of estimates of gene effects under different environmental conditions.

11. Objectives

The keeping this in view, the present investigation on "Identification of superior parents and hybrids based on heterosis, combining ability, gene action and stability in cotton (*Gossypium hirsutum* L.)" will be undertaken with the following objectives:

1. To study the nature and magnitude of heterobeltiosis and standard heterosis for seed cotton yield and its components
2. To estimate the general and specific combining ability effects of parents and crosses, respectively for seed cotton yield and its components
3. To estimate stability parameters for seed cotton yield and its components
4. To identify elite parents and crosses on the basis of heterosis, combining ability effects and stability performance

12. Review of Literature

The following subheadings provide a brief summary of the existing literature and information related to the current investigation:

12.1 Heterosis

In the field of crop improvement, breeders are the most frequent users of the term heterosis. Heterosis breeding is the core of modern plant breeding. It is regarded as an important development in breeding techniques. Koelreuter (1766) gave the first evidence of heterosis. He observed that as parental diversity increased, it also increased crosses' vigour. Shull (1908) is credited with coining the term "heterosis". It is the occurrence where the F_1 hybrid produced by crossing two genetically different individuals exhibits greater vigour than the better or mid-parent value. The term "heterobeltiosis" was later used by Fonseca and Patterson (1968) to explain the improvement of heterozygotes in relation to better parents.

Rani *et al*. (2020) studied of 20 F_1 hybrids created by crossing four lines with five testers in a line × tester mating design were examined and RCH 659 was used as a standard check. F 2453 × L 765 had the lowest seed cotton production (1905 kg/ha), while TCH 1716 × HYPS 152 had the highest seed cotton yield and lint yield (3078 kg/ha and 1173 kg/ha, respectively). Five of the twenty hybrids showed a significant positive heterosis over the midparent. Standard heterosis varied from –27.84 (GSHV 179 × L 766) to 16.80 (TCH 1716 × L 766) per cent, whereas heterobeltosis ranged

from –21.44 (F 2453 × GJHV 516) to 41.00 (TCH 1716 × L 766) per cent. In addition to seed cotton yield per plant, the cross combinations TCH 1716 × L 765, TCH1716 × L 766, GSHV 179 × L 765 and F 2453 × L 766 showed substantial and positive heterosis for number of bolls per plant, boll weight, number of sympodia per plant and lint index.

Abdelmoghny (2021) examined eighteen F_1 crosses obtained from six lines crossed with three testers in a line × tester mating design. Out of eighteen crosses, seven crosses *viz.,* Giza 85 × 10229, Giza 90 × Pima S6, Giza 94 × 10229, Giza 95 × Suvin, Giza × PIMA S6, Giza 95 × 10229 and Giza 96 × Pima S6 showed higher seed cotton yield per plant and lint cotton yield per plant more than the average crosses mean, while, lint percentage was more than 40 per cent for the seven crosses. The six crosses for fiber quality traits came into the long staple group, while the seventh one came into the extra-long staple category. The other two crosses (Giza 96 × Suvin and Giza 96 × 10229) expressed stronger fiber quality traits as an extra-long staple and had high yield component qualities that were lower than the crossings mean. Thus, the cotton breeder was able to eliminate the negative correlation between fiber quality attributes and yield. Four crosses *viz.,* Giza 85 × 10229, Giza 85 × Pima S6, Giza 85 × Suvin and Giza 90 × Pima S6 had low fiber strength value (less than 10).

Gnanasekaran and Thiyagu (2021) estimated standard heterosis for eleven quantitative and five quality characters in cotton using twelve parental genotypes and twenty F_1s hybrids developed in a line × tester method. The best hybrids for seed cotton yield were found to be SVPR 2 × TSH 325 followed by SVPR 2 × Suraj and GJHV 370 × PBH 116; for fiber qualities, SVPR 2 × TCH 1828 was suggested for heterosis breeding. Additionally, for recombination breeding for earliness and ginning percentage the hybrid GJHV 370 × CPD 1702 was recommended.

Subhashini *et al*. (2022) examined 35 hybrids of *Gossypium hirsutum* L. for heterosis. Seven lines and five tests were crossed to create these hybrids. The hybrid TCH 1828 × RHC 1409 had the highest significant mid and better parent heterosis for ginning outturn, while the hybrid TCH 1199 × GTHV 323 demonstrated the highest mid and better parent heterosis for the lint index. In the hybrid BSH 18 × RHC 1409, the characters with the highest significant mid and better parent values were found to be boll weight and seed cotton yield per plant. The number of sympodial branches per plant and number of bolls per plant in the hybrid CO 14 × KC 3, which has the highest standard heterosis among the 35 hybrids, are qualities that contribute to yield.

Madugula *et al*. (2023) generated eighteen hybrids by crossing three lines and six testers in line × tester design. The best F_1 hybrids were found to be TCH 1837 × Lam GPC 117 followed by GISV 298 × Lam GPC 274 and GISV 298 × Lam GPC 51. These hybrids could be exploited through heterosis breeding because they showed significant *per se* performance and better parental heterosis for important yield and fiber quality traits.

Suresh (2023) examined 56 cross combinations with 15 parents (7 lines and 8 testers) and four checks (NHH-250, NHH-715, DCH-32 and Phule Dhara). In comparison to the best check, the intra-specific cross NH-615 × NH-452 (128.31 g) had a much higher seed cotton production, followed by RCH-688 × PH-1009 (119.27 g), NH-615 × AKH-8828 (118.14 g), NH-635 × AKH-8828 (115.87 g), NH-615 × AKH-1301 (112.90), NH-635 × NH-452 (105.12 g) and NH-615 × AKH-9916 (103.32 g). The best heterotic crosses for seed cotton yield per plant and some of its contributing traits, such as number of sympodia per plant, number of bolls per plant, boll weight, harvest index and one to two fiber qualities, have been observed to be NHH-715 (93.72 g) and those crosses, which also found significant standard heterosis and high mean performance.

Udaya *et al*. (2023) examined the degree of heterosis in crosses between five testers and eight elite selected lines in upland cotton (*Gossypium hirsutum* L.). A randomized block design was used to analyse the productivity features and fiber quality of the 40 hybrids that were produced through line × tester crossing. The most likely crossings were CPD-462 × SCS-1061, FLT-36 × SCS-106 and CPD-462 × NNDC-30. Desired fiber quality values were also recorded by crosses CPD-462 × IH-11 and FLT-44 × NNDC-24. Due to their high *per se* performance and significant heterosis for the majority of yield and fiber quality parameters, these crosses can be used for crop development initiatives.

Rajani *et al.* (2024) evaluated 45 hybrids developed through line × tester mating design, along with nine lines, five testers and standard check hybrid (G.Cot.Hy-22) in cotton. For seed cotton yield per plant, heterosis over superior parent varied from -22.57 to 50.26% in E_1, -12.99 to 52.79% in E_2 and -11.65 to 51.87% in E_3, whereas heterosis over standard check hybrid ranged from -31.10 to 27.76% in E_1, -23.71 to 35.21% in E_2 and -21.10 to 24.46% in E_3. Four crosses in E_1, six crosses in E_2 and four crosses in E_3 over standard check showed significant and positive heterosis, whereas 12 crosses in E_1, 16 crosses in E_2 and 11 crosses in E_3 over better parent demonstrated the

performance of crosses in individual environments with regard to seed cotton yield per plant. The cross combinations GJHV-522 × GJHV-503 and GTHV-13/32 × GJHV-585 were the most promising combinations for seed cotton yield per plant across various environments based on *per se* performance, heterobeltiosis and standard heterosis.

Patel *et al.* (2025) evaluated heterosis in cotton (*Gossypium hirsutum* L.). Ten cotton genotypes (6 lines and 4 testers) and a standard check (G. Cot. Hy-18) in a line × tester design were used to create 24 F_1 hybrids. Analysis of variance revealed significant variation in seed cotton yield, boll weight and fiber quality traits, providing an opportunity for improvement. The hybrids that performed the best were 76IH20 × V-797, GJHV-503 × G. Cot-15 and 76IH20 × Deviraj, which demonstrated better heterosis for yield and fiber characteristics. Furthermore, the hybrid GJC-101 × V-797 performed exceptionally well in terms of weight and boll production.

Sharma *et al.* (2025) was conducted experiment using five parental lines, four tester and two checks *viz*., NHH 44 BG II and Suraj Bt. For the traits like number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield, the crosses NH 22340 Bt × NH 22308 Bt, NH 22482 Bt × NH 22384 Bt, NH 22482 Bt × NH 22308 Bt and NH 22279 Bt × NH 22254 Bt showed the highest levels of heterobeltiosis and standard heterosis. For specific fiber quality traits like UHML, micronaire value, fiber strength and uniformity ratio, the crosses NH 22340 Bt × NH 22384 Bt, NH 22482 Bt × NH 22308 Bt, NH 22482 Bt × NH 22254 Bt, NH 22340 Bt × NH 22294 Bt and NH 22316 Bt × NH 22308 Bt reported the highest levels of heterosis over better parent, standard check variety and standard hybrid.

12.2 Combining ability and gene action

Sprague and Tatum (1942) first proposed the idea of general and specific combining ability as a gauge of gene effects. They claim that although Specific Combining Ability (SCA) assesses the performance deviation of particular cross combinations based on the performance of the parents involved, General Combining Ability (GCA) measures the average performance in a series of cross combinations.

Bankar *et al.* (2020) conducted research to gather data on the magnitude of GCA variations and effects for individual parents as well as SCA variances and effects of *Gossypium hirsutum* hybrids for seed cotton yield and its characteristics. Fifty hybrids were produced by crossing five females with ten testers in a line × tester mating design. Gregg 45, MESR 17, SR 38 and Pusa 31 were shown to be good general combiners among males, whereas H 1300 and H 1098 among females were found to have the best

per se performance for all the attributes examined. For seed cotton yield and its yield qualities in a desirable direction, the crosses H 1117 × LRA 5166 (poor × poor GCA), H 1226 × SR 38 (good × good GCA), H 1098I × PUSA 31 (good × excellent GCA) and H 1300 × AVB SM 277 (good × poor GCA) demonstrated high *per se* performance with good SCA effects. For every variable, magnitude of SCA variance was greater than GCA variance that indicated the preponderance of non-additive gene action a crucial factor in the exploitation of heterosis through hybrid breeding.

Gnanasekaran and Thiyagu (2021) evaluated 20 F_1s along with 12 parents and two standard checks (RCH 659 BG II and Mallika NBt) With the exception of days to 50 per cent flowering, every attribute examined showed higher SCA variance than GCA variance, indicating that dominant gene action controls these traits. For the number of bolls per plant and seed cotton yield, line SVPR 2 was the best general combiner among the parents used; for the number of bolls per plant, lint index and seed cotton yield, tester TSH 325 was the best general combiner. Additionally, it must to be taken into consideration while creating hybrids or recombinants. Since the hybrid GJHV 370 × CPD 1702 met the requirements of considerable gca effects for respective parent and non-significant sca effects for the hybrid, it was recommended for recombination breeding for earliness and ginning percentage.

Subhashini *et al*. (2022) carried out line × tester analysis in cotton with 7 lines and 5 testers resulting Thirty-five F_1 hybrids were evaluated for study of combining ability. Combining ability analysis shows that non-additive gene action predominates in all parameters that contribute to yield and fiber quality. For yield and quality attributes, CO 14 and TCH 1828 were shown to be the best combiners among the lines. Out of the five testers, KC 2 and KC 3 were determined to be the best. The hybrid BSH 18 × RHC 1409 showed the highest sca for boll weight and seed cotton yield per plant, while the hybrid BSH 18 × GISV 323 showed the highest sca for quality traits like ginning outturn and upper half mean length; the best-performing hybrids were TCH 1828 × KC 3 and CO 14 × KC 2 for sca values for quality traits like elongation length and micronaire values.

Madugula *et al*. (2023) studied the combining ability and gene action for eighteen F_1s were developed by crossing three lines (females) and six testers (males) in line × tester design. The characters *viz.*, Ginning outturn, seed cotton yield, lint yield and fiber quality characteristics were found to have non-additive gene action, however the upper half mean length and uniformity index showed a prevalence of additive gene

action. The lines SCS 1207, GISV 298 and tester Lam GPC 235 were found to be the best combiners for ginning outturn, seed cotton yield and lint yield, while TCH 1837 (line) and Lam GPC 274 (tester) were found to be the best general combiners for the traits bundle strength and elongation. The best hybrids were found to be the F_1 hybrids TCH 1837 × Lam GPC 117, GISV 298 × Lam GPC 274 and GISV 298 × Lam GPC 51, which exhibit strong positive SCA effects for significant yield and fiber quality characteristics. For key yield components and fiber quality characteristics, the cross combinations GISV 298 × Lam GPC 235 and SCS 1207 × Lam GPC 355 exhibited non-significant SCA effects for the respective hybrids and considerably high GCA effects for the parents.

Suresh (2023) generated 56 F_1s from seven *hirsutum* lines have been crossed with eight testers (two *barbadense* and six *hirsutum*) in line × tester fashion along with four checks NHH-250, NHH-715, DCH-32 and Phule Dhara. Among the parents, lines NH-635 and RCH-688 were found to be good general combiners for seed cotton yield per plant, while line NH-615 was found to be a good general combiner for all characters except days to maturity, plant height, seed index and lint index. The testers AKH-1301, AKH-9916, AKH-8828 and NH-452 were found to be good general combiners for seed cotton yield per plant, while PH-1009 was found to be a good combiner for all charters except seed index. Days to 50 per cent flowering, days to 50 per cent boll bursting, days to maturity, number of sympodia per plant, number of bolls per plant, boll weight and uniformity ratio were all predictability ratios greater than unity, suggesting the significance of additive gene action for these traits, which can be exploited through selection in segregating generation. Additionally, the predictability ratio for seed cotton yield per plant was extremely near to unity, suggesting that both additive and non-additive gene activity are present and can be utilized through heterosis breeding and selection. For the traits plant height, seed index, lint index, harvest index, ginning outrun, upper half mean length, micronaire value and fiber strength, the estimate of variance components showed that the SCA variance was larger than the corresponding GCA variance. Heterosis breeding can be used to take advantage of non-additive gene action for governing these traits, as shown by a GCA/SCA ratio less than unity.

Patel *et al* (2025) assessed combining ability and gene action in cotton (*Gossypium hirsutum* L.). A total of 24 F_1 hybrids were created using 10 cotton genotypes (6 lines and 4 testers) along with a G. Cot. Hy-18 (standard check) in a line × tester design. Significant variation in boll weight, fiber quality traits and seed cotton

yield was found by analysis of variance, suggesting an opportunity for improvement. While additive gene action was predominant for earliness parameters like blooming and boll bursting, nonadditive gene action was noted for seed cotton yield, boll production and fiber quality. For seed cotton yield, boll weight and fiber quality, the lines 76IH20 and GJHV-510 as well as the tester Sanjay (CJ-73) were found to be efficient general combiners. Strong performance and high SCA effects for yield and fiber qualities made 76IH20 × V-797, GJHV-503 × G. Cot-15 and 76IH20 × Deviraj stand out as the best hybrids. Furthermore, there is great potential for the hybrids GJC-101 × V-797. The prevalence of non-additive gene activity was supported by the variance ratio (σ^2GCA/σ^2SCA) being less than one.

Sharma *et al.* (2025) carried out an investigation to estimate combining ability suitable for identify superior parents and cross combinations using 20 F_1s, five lines and four testers along with two checks (NHH 44 BG II and Suraj Bt). The parent NH 22257 Bt, NH 22384 Bt, NH 22279 Bt, NH 22340 Bt and NH 22308 Bt were found to be good general combiners for yield, yield contributing and fiber quality traits. High estimates of SCA effects for many traits were found in crosses NH 22279 Bt × NH 22254 Bt, NH 22316 Bt × NH 22384 Bt, NH 22340 Bt × NH 22384 Bt, NH 22279 Bt × NH 22308 Bt and NH 22257 Bt × NH 22384 Bt. The experiment revealed that non-additive variance predominated for all characters.

El-Seidy *et al*. (2026) carried out an experiment using line × tester mating design, in which 6 lines paired with 3 tester. With the exception of the uniformity index in testers, which did not exhibit any discernible variation, significant genetic variability was found among genotypes, parental lines, their hybrids and interactions (line × tester) for the majority of variables. Compared to testers, female lines made a larger contribution to the overall variance for the majority of characteristics. With values ranging from 13.64 per cent for boll weight to 71.93 per cent for fiber strength, narrow-sense heritability estimates were generally modest, indicating a minor role of additive genetic effects in trait expression. Limited environmental influence on trait variability is indicated by the minimal difference between the genotypic (GCV%) and phenotypic (PCV%) coefficients of variation. While genotypes Giza 83 and Giza 96 excelled in fiber quality features, genotypes Giza 94 and Australly 13 showed greater general combining ability for yield traits.

12.3 Genotype × Environment interaction and stability analysis

Stability research provides information about genotypic variance and how different genotypes respond to various environments. Isolating widely adopted genotypes that are appropriate for particular environments also helps. A phenotype is the outcome of genotype and environment interacting. For agriculturally important traits, the desired genotypes may exhibit low genotype × environment interaction. Because they can alter their genotypic and phenotypic status in response to shifting environmental conditions, these genotypes are thought to be more stable. Another term used for this is genetic homeostasis (Lerner, 1954). The idea of a regulatory system allows for bond diversity and allows the organism to live and can be helpful in set of environmental conditions.

Eberhart and Russell (1966) developed an improved regression technique for studying genotype stability. They proposed that while evaluating genotype stability, both linear (bi) and non-linear (S^2di) components of the G × E interaction should be taken into account. They also stated that a high mean, unit linear regression (bi;1) and least deviation from regression ($S^2di;0$) are characteristics of an ideal variety.

According to the significance of the G × E interaction and stability characteristics in F_1, stable segregants are likely to be produced in subsequent generations among the F_1s that are stable in a number of environments. Such F_1s may exhibit stability when proposed as hybrids for commercial production and those hybrids may be preferred for the selection of desirable genotypes. The following details of the reviews that are available for the G × E interaction and stability parameters in cotton.

Sirisha *et al.* (2019) conducted a study utilizing the Eberhart and Russell Model for the yield-contributing characteristics in cotton to determine the stability of 45 intra-*hirsutum* hybrids grown in three different locations. Significant mean sum of squares resulting from genotypes and environment linear for every character were found by analysis of variance. With the exception of days to 50 per cent flowering, the number of sympodia per plant and the seed cotton yield per plant, the pooled deviation was significant for all characters, highlighting the significance of both linear and non-linear components in determining the interaction of the genotypes with environment in the present study. After extensive testing with check varieties and hybrids across locations, seven hybrids were proven to be stable for seed cotton yield per plant. These hybrids can be used for commercial cultivation.

Abro *et al.* (2020) evaluated sixteen cotton strains and two commercial check types, CIM-496 and CRIS-134 were assessed over the course of two years at five different locations. The mean square for seed cotton yield for genotypes and genotype x environment interaction (G × E) were shown to be very significant by the findings of the combined analysis of variance. With a low regression coefficient and deviation from the regression coefficient, genotype NIA-M-30 demonstrated the highest seed cotton production. The regression coefficient and variation from the regression coefficient for the other four genotypes *viz.,*NIA-80, NIA-83, NIA-Bt-2 and NIA-Perkh; also showed greater yield, indicating a wide range of environmental adaptation. The cotton genotypes NIA-HM-327, NIA-84 and NIA-HM48 displayed high regression coefficients, indicating their unique adaption to favourable environments.

Vavadiya *et al.* (2021) investigated the stability of 50 hybrids across environments using three distinct sowing dates utilizing a line × tester analysis with ten lines and five testers. With the exception of days to 50 per cent flowering, days to 50 per cent boll bursting, seed index and oil content, which showed a linear response of different genotypes for various traits under multiple environmental conditions, genotype × environment interactions were not significant for any of the features. When compared to pooled error and pooled deviation, the variance due to environments (linear) was significant for every characteristic. The hybrids G.Cot 18 × GSHV 173, G.Cot 12 × G.Cot 20, G.Cot 18 × GTHV 7/70, G.Cot 12 × GTHV 7/70 and GJHV 511 × GSHV 173 were the most widely adapted and stable crosses for seed cotton yield per plant and its components, according to the stability parameters, namely overall mean ($\bar{X}$), regression coefficient (bi) and deviation from regression (S^2di). The stable genotypes for seed cotton yield and its components were found to include parents GJG 101, Deviraj, G.Cot 12, G.Cot 10, GJHV 500, GJHV 511, GJHV 517, GJHV 521, GJHV 536, Suraj, G.Cot 20, GSHV 173 and GTHV 7/70.

Murthy and Pradeep (2022) was carried out experiment in three distinct sites *viz*., Aswaraopet (E_1), Warangal (E_2) and Adilabad (E_3) to find stable cotton genotypes utilizing 42 crosses produced by crossing six lines and seven testers in a line × tester design. Because of their individual buffering capacities, heterozygotes were shown to be more stable than homozygotes. The hybrids MC 4-3 × MC 3-2, MC 5-1 × MC 11-1, MC 4-3 × MC 22-2, MC 4-3 × NH 630 and MC 5-1 × NH 630 all demonstrated a strong correlation between heterobeltiosis and specific combining ability. They also demonstrated stable performance under poor, moderate (E_1, E_2) and better (E_3)

environments, whereas MC 17-6 × MC 17-1, MC 4-3 × MC 3-2 and MC 16-3 × MC 17-2 had out yielded homozygous parents in poor environments and displayed both heterosis and sca effects.

Suresh (2023) evaluated 56 cross combinations, 15 parents (7 lines and 8 testers) and four checks (NHH-250, NHH-715, DCH-32 and Phule Dhara) with two replications at Cotton Research Station, Mahboob Baugh farm, Parbhani (E_1), Cotton Research Station, Nanded (E_2) and NARP, Aurangabad (E_3). Boll weight, seed index, lint index, fiber length, micronaire value and fiber strength seemed among characteristics for which the environment was non-significant, but the analysis of variance for stability showed significant variance due to genotypes for all the characters. For every characteristic except boll weight, seed index, lint index, micronaire value, fiber strength and uniformity ratio, the mean square due to environment (linear) and G × E (linear) interaction was extremely significant. Additionally, for every attribute except boll weight, seed index, lint index, micronaire value and fiber strength, the mean square due to pooled deviation was found to be significant. Parental lines AKH-8828, PH-348, NH-615 and tester RCH-688 and crosses *viz*., NH615 × NH-452, RCH-688 × PH-1009, NH-615 × PH-1009, NH-635 × AKH-8828 and NH-635 × NH-452 were well adapted over the environments for seed cotton yield per plant.

Dimitrova and Koleva (2025) examined 24 advanced cotton lines and the conventional cultivar Chirpan-539 for genotype × environment interaction and stability. In terms of boll weight, lines 701, 581 and 678 performed the best; in terms of lint percentage, lines 661, 663 and 718 were the most valuable; and in terms of fiber length, lines 724, 721 and 583 had a complex breeding value. Based on all stability techniques, these lines showed high average levels and high stability for the pertinent features. The following lines showed complex breeding value, high average level and high stability for two traits at the same time: 678 for boll weight and seed cotton yield; 701 for boll weight and lint percentage; and 581 for boll weight and fiber length.

Rajani and Valu (2025) evaluated 45 crosses created using a line × tester mating design (nine lines and five testers) along with 14 parents grown under three dates of sowing (environments) E_1, E_2 and E_3, stability analysis for seed cotton yield and its attributing traits was carried out in accordance with Eberhart and Russell (1966). When compared to pooled error, the G × E interaction was significant for the majority of traits with the exception of boll weight and plant height. Significant effects against pooled

error and pooled deviation were found for all traits when the combined effect of E + (G × E) was taken into account. The environment (linear) component accounted for a fairly high percentage of the total variance. This showed that different sowing dates had a generally linear effect and were justified. The most widely adapted and stable five crosses for seed cotton yield per plant and its components were GJHV-522 × GJHV-503 followed by GJHV-548 × GJHV-585, TCH-1828 × GJHV-503, GBHV-187 × GJHV-503 and GISV-365 × GJHV-503, according to the stability parameters overall mean ($\bar{X}$), regression coefficient (bi) and deviation from regression (S^2di). The stable parental genotypes for seed cotton yield and its components were GBHV-187, GJHV-548 and GJHV-585.

13. Materials and Methods

13.1 Location : Cotton Research Station
Junagadh Agricultural University
Junagadh

13.2 Year and season of experiment

a) For development of experimental materials : *Kharif*– 2025-26

b) For evaluation of experimental materials : *Kharif*– 2026-27

- Three dates of sowing : E_1 - Onset of monsoon
  E_2 - 20 days after 1st sowing
  E_3 - 20 days after 2nd sowing

13.3 Crossing pattern : Line × Tester mating Design

13.4 Experimental design : Randomized Block Design (RBD)

13.5 No. of treatment : Sixty [14 Parents + 45 Hybrids + 1 Standard check (G.Cot.Hy-22)]

13.6 No. of replications : 3 (Three)

13.7 Spacing : 120 cm × 45 cm

13.8 List of genotypes used for crossing

Lines (Female)	Testers (Male)	Standard Check
1. GJHV-621	1. Deviraj	1. G.Cot.Hy-22
2. GJHV-622	2. GBHV-176	
3. GJHV-625	3. G.Cot-38	
4. GJHV-626	4. GISV-267	
5. GJHV-627	5. GTHV-6/2	

6. GJHV-628
7. GJHV-629
8. GJHV-630
9. GJHV-632

13.9 Observations to be recorded

Five competitive plants from each entry in each replication will be randomly selected before flowering and tagged for the purpose of recording observations on different characters and their average values will be used in the statistical analysis.

13.9.1 Days to first flower

The number of days taken from the date of sowing to appearance of first flower will be counted as days to first flower.

13.9.2 Days to first boll opening

The number of days taken from the date of sowing to date of boll opening will be counted as days to first boll opening.

13.9.3 Plant height (cm)

The plant height of the main stem from the ground level to the growing point of selected plants will be measured in centimetres at the time of last picking.

13.9.4 Number of monopodia per plant

Total numbers of monopodia on main stem of the selected plants will be counted at the time of last picking.

13.9.5 Number of sympodia per plant

Total numbers of sympodia on main stem of the selected plants will be counted at the time of last picking.

13.9.6 Number of bolls per plant

Total number of healthy, fully mature and open bolls from selected plants which yielded seed cotton will be counted at each picking and finally total number of bolls per plant will be counted at the time of last picking.

13.9.7 Boll weight (g)

Five fully mature, healthy and open bolls from each of the selected plants will be randomly picked up and seed cotton obtained from these bolls will be weighed in grams and averaged.

13.9.8 Seed cotton yield per plant (g)

The seed cotton yield per picking will be recorded separately from each of the selected plants of each entry and summed up for each plant for all the pickings and

weighed in grams and averaged.

13.9.9 Ginning percentage (%)

A random sample of 100 g of seed cotton from selected plants will be used to calculate ginning percentage (GP). Ginning percentage is the ratio of weight of lint to that of seed cotton expressed as percentage. After ginning of seed cotton of selected plants ginning percentage will be calculated as per the following formula;

$$\text{Ginning percentage (\%)} = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

13.9.10 Seed index (g)

The weight of 100 matured seeds in grams obtained from the selected plants will be recorded as seed index.

13.9.11 Lint index (g)

Lint index represents the absolute weight of lint produced per seed. It will be calculated as per the following formula;

$$\text{Lint index (g)} = \frac{\text{Weight of 100 seed (g)} \times \text{Ginning \%}}{\text{100-Ginning \%}}$$

13.9.12 Oil content (%)

A random sample of oven dried seeds will be taken from the selected plants and oil content will be determined in percentage by using Nuclear Magnetic Resonance Technique (Tiwari *et al*., 1974).

13.9.13 Span length (mm)

Span length is a new concept of length parameter. This term can be defined as the distance spanned by a specified percentage of fibers in the specimen being tested when the fibers are parallelized and randomly distributed. The most commonly used measure is 2.5 % span length, which corresponds with the American Classers' staple length.

13.9.14 Fiber strength (g/tex)

Fiber strength will be measured at 3.2 mm gauge on the stelometer.

13.9.15 Fiber fineness (mv)

The micronaire value indicates the extent of resistance of flow by fiber plugs. It is expressed as micrograms per inch (*i.e.* 10^{-6} g/inch).

14. Statistical Analysis

The statistical analysis will be done by using average value of selected plants from each genotype and each replication in all the three dates (environments) for the following aspects.

14.1 Analysis of variance for experimental design

The analysis of variance for the experimental design will be carried out using Randomized Block Design separately for all the characters as per Panse and Sukhatme (1995).

14.2 Estimation of heterosis

It is more relevant to use data from better parents for heterobeltiosis as well as to verify variety for analysis of standard heterosis, sometimes referred to as economic heterosis, when estimating heterosis.

(A) Heterobeltiosis

According to Fonseca and Patterson (1968), heterobeltiosis is determined as the deviation of F_1 above the better parent. The method to represent this deviation in percentage is as follows:

$$\text{Heterobeltiosis (\%)} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\bar{F}_1$ = Mean performance of F_1

$\overline{BP}$ = Mean value of better parent of respective cross combination

(B) Standard heterosis

It is superiority of F_1 over the standard commercial hybrid (G.Cot.Hy-22) and will be calculated as below:

$$\text{Standard heterosis (\%)} = \frac{\bar{F}_1 - \overline{SC}}{\overline{SC}} \times 100$$

Where,

$\bar{F}_1$ = Mean performance of F_1

$\overline{SC}$ = Mean performance of the standard check commercial hybrid (G.Cot.Hy-22)

14.3 Combining ability analysis

(a) Combining ability analysis for individual environment

The combining ability analysis will be carried out according to the method suggested by Kempthorne (1957). This design is related to North-Carolina Design II (Comstock and Robinson, 1952) in terms of covariance of half-sibs and full-sibs.

(b) Combining ability analysis over environments

In order to obtain information on the influence of genotype × environment interaction on combining ability estimates, pooled analysis of variance for combining ability over the environments will be carried out.

14.4 General and specific combining ability effects over environments

General combining ability effect of lines and testers and specific combining ability effect of cross combinations under individual environment and over environments will be calculated.

(i) General combining ability effects of females

$$\hat{g}_i=(Y_i\ldots/lmr)-(Y\ldots/lmfr)$$

Where,

l = Number of environments

m = Number of males

f = Number of females

r = Number of replications

Y….= Total of all hybrids in all replications over environments

Y_i…= Total of i^{th} female over all males, replications and environments

(ii) General combining ability effects of males

$$\hat{g}_j=(Y_{.j}../lfr)-(Y\ldots/lmfr)$$

$Y_{.j}..$ = Total of j^{th} male over all females, replications and environments

(iii) Specific combining ability effects of cross combinations

$$S_{ij} = (Y_{ij}../lr) – (Y_i\ldots/lmr) - (Y_{.j}../lfr) + (Y.../lmfr)$$

$Y_{ij..}$= ij^{th} cross combination total over all replications and environments

The significance of GCA and SCA effects were tested using critical difference,

which was calculated as follows:

$$SE\ (GCA\ for\ females)=\sqrt{Me/lmr}$$

$$SE\ (GCA\ for\ males)=\sqrt{Me/lfr}$$

$$SE\ (GCA\ for\ crosses)=\sqrt{Me/lr}$$

$$CD = SE \times t_{0.05}\ value\ at\ error\ degrees\ of\ freedom$$

14.5 Genotype × Environment interaction and stability analysis

The statistical analysis for genotype × environment interaction and stability will be carried out according to the procedure outlined by Eberhart and Russell (1966) for seed cotton yield and its components.

15. References

Abdelmoghny, A. (2021). Combining ability in relation to heterosis effects and genetic diversity in cotton using line × tester mating design. *Plant Archives*, **21(1)**:1-9.

Abro, S., Rajput, M. T., Sial, M. A., Deho, Z. A. and Rizwan, M. (2020). Stability analysis for seed cotton yield of newly developed upland cotton genotypes. *Advances in Agriculture and Animal Sciences*, **36(2)**: 97-100.

Anonymous, 2025. ICAR - All India coordinated research project on cotton- Annual Report 2024-25.

Bankar, A. H., Sangwan, O., Nirania, K. S., Kumar, A. and Sagar. (2020). Combining ability analysis for seed cotton yield and its attributing traits in upland cotton (*Gossypium hirsutum* L.).

Comstock, R. E. and Robinson, H. F. (1952). Estimation of average dominance of genes. In "Heterosis". (Ed. G. W. Gowen), Iowa State College Press, Ames, Iowa, pp. 494-516.

Cooper, M. and DeLacy, I. H. (1994). Relationship among analytical methods used to study genotypic variation and genotype by environment interaction in plant breeding multi-environment. *Theoretical and Applied Genetics*., **88**: 561-572.

Dimitrova, V. and Koleva, M. (2025). Phenotypic stability of new cotton lines (*Gossypium hirsutum* L.). *Bulgarian Journal of Agricultural Science*, **31(3)**: 531–544.

Eberhart, S. A. and Russell, W. A. (1966). Stability parameters for comparing the varieties. *Crop Science*, **6**: 36-40.

El-Seidy, E. S. H., El-Razek, U. A. A., Yehia, W., El-Shazly, M. W. and Turkey, H. S. (2026). Estimation of gene action for quantitative traits related to yield components in cotton. *Egyptian Journal of Agronomy*, **48(1)**: 83-86.

Fonesca, S. and Patterson, F. C. (1968). Hybrid vigour in seven parent diallel in common wheat (*Triticum aestivum* L.). *Crop Science*, **8**: 85-88.

Gnanasekaran, M. and Thiyagu, K. (2021). Gene action, combining ability and standard heterosis for seed cotton yield and fiber quality components in upland cotton. *Electronic Journal of Plant Breeding*, **12(2)**: 325-334.

Kang, M. S. (1998). Using genotype by environment interaction for crop cultivar development. *Advanced in Agronomy*, **62**: 199-252.

Kempthorne, O. (1957). An Introduction to Genetic Statistics. John Willey & Sons Inc., New York.

Koelreuter (1766). Principles of Plant Breeding (Ed. R. W Allard). John Wiley and Sons Inc., New York, p. 214.

Lerner, L. M. (1954). Genetic Homeostasis. Oliver and Boyd. London.

Madugula, S. R., Chapara, R., Reddy, K. S., Lakshmi, B. S. and Pranaya, J. (2023). Combining ability and heterosis studies for seed cotton yield and fiber quality traits in *hirsutum* cotton. *Electronic Journal of Plant Breeding*, ***14*(2)**: 439-447.

Murthy, K. G. K. and Pradeep, T. (2022). Influence of G × E interaction on heterobeltiosis, combining ability and stability of multiple cross derivatives of cotton (*Gossypium hirsutum* L.) amenable for HDPS. *Indian Journal of Genetics and Plant Breeding*, **82(03)**: 359-360.

Panse, V. G. and Sukhatme, P. V. (1995). *Statistical Methods for Agricultural workers*, ICAR, New Delhi.

Patel, J. D., Dubey, N., Delvadiya, I. R., Avinashe, H. and Keerthana, S. (2025). Assessment of heterosis and combining ability for yield and oil traits in cotton (*Gossypium hirsutum* L.) contributing to the revival of India's cotton sector. *Journal of Applied and Natural Science*, **17(3)**: 1227.

Rajani, C. J. and Valu, M. G. (2025). Evaluating the stability of seed cotton yield and its key components over environments. *Plant Archives,* **25**: 405-412.

Rajani, C. J., Valu, M. G., Madariya, R. B., Vekaria, D.M., Dudhat, H. and Bhut, N. M. (2024). Heterosis for seed cotton yield and its components in cotton

(*Gossypium hirsutum* L.) over the environments. *Frontiers in Crop Improvement,* **12**: 758-762

Rani, S., Chapara, M. and Satish, Y. (2020). Heterosis for seed cotton yield and yield contributing traits cotton (*Gossypium hirsutum* L.). *International journal of chemical studies*, **8(3)**: 2496-2500.

Sharma, B., Baig, K. S., Deshmukh, S. S. and Praveenkumar, G. (2025). Heterosis and gene action studies in Bt cotton (BGI) (*Gossypium hirsutum* L.). *Plant Archives*, **25(1)**: 2281-2292.

Shull, G. H. (1908). The composition of a field of maize. *Journal of Heredity*, **(1)**: 296-301.

Simpson, D. M. 1954. U. S. Department of Agriculture. Tech. Bull., 1094.

Sirisha, A. B. M., Lal Ahamed, M., Ramakumar, P. V., Ratnakumari, S. and Srinivasa Rao, V. (2019). Stability analysis for seed cotton yield and its component traits in upland cotton (*Gossypium hirsutum* L.). *Science Spectrum*, ***4*(1-2)**: 18-27.

Sprague, G. F. and Tatum, L. A. (1942). General versus specific combining ability in single crosses of corn. *Journal of American Society of Agronomy*, **34(1):** 923-932.

Subhashini, S., Rajeswari, S., Premalatha, N., Kalaimagal, T., Muthuswami, M. and Jeyakumar, P. (2022). Combining ability and heterosis for yield contributing and fiber quality traits in the hybrids of *Gossypium hirsutum* L. *Electronic Journal of Plant Breeding*, **13(2)**: 645-654.

Suresh, D. A. (2023). Studies on heterosis, combining ability and stability for yield and fiber quality traits in intra (*G. hirsutum* L. x *G. hirsutum* L.) and inter (*G. hirsutum* L. x *G. barbadense* L.) specific. Ph.D. (Agri.) Thesis (Unpublished). Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Tiwari, P. N., Gambhir, P. M. and Rajan, T. S. 1974. Rapid and nondestructive determination of seed oil by pulsed nuclear magnetic resonance technique. *Journal of the American Oil Chemists' Society*, **51**: 104-109.

Udaya, V., Saritha, H. S. and Patil, R. S. (2023). Heterosis studies for seed cotton yield and fiber quality traits in upland cotton (*Gossypium hirsutum* L.). *Indian Journal of Agricultural Research*, ***57*(2)**: 150-153.

Vavdiya, P. A., Chovatia, V. P., Bhut, N. M. and Vadodariya, G. D. (2021). G × E interactions and stability analysis for seed cotton yield and its components in cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding*, **12(2)**: 396-402.

Signature of Student	Signature of Major Guide
(Katariya Yogeshbhai Pravinbhai)	(M. G. Valu)